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Relationship between mascavo sugar granulometry and color

Vinicius Pariser Marques XAVIER[1], Claudio Takeo UENO[1], José Luis Franco de GODOY[2], Marta Regina VERRUMA-BERNARDI[2*], Lyssa Setsuko SAKANAKA[1]

Abstract

The aim of this study was to evaluate the effect of the size of mascavo sugar crystals in their instrumental and sensory color. Nine sugar samples were used, sieved, and separated by meshes of 600, 425, and 300 µm. For the instrumental color analysis, a portable colorimeter was used, and 20 untrained panelists participated in the sensory analysis of color difference. The original samples were evaluated regarding moisture, polarization, and ashes, and the average mesh aperture and hue value calculations were estimated. Seven of the nine sugar samples evaluated were retained in three meshes. The largest sugar fractions were evaluated as darker (600 µm) in the instrumental analysis and perceived by the panelists with higher color intensity. The alteration in sugar crystal size changed color, and the most impactful variable in differentiating sensory color between meshes for each sugar sample was the average aperture, indicating that luminosity and hue did not present discriminatory power between the different granulometries, but they are potential indicators of appearance difference between the samples without sieving.

Keywords: ranking test; appearance; luminosity; sensory analysis.

Practical Application: The granulometry of brown sugar significantly impacted its instrumental and sensory color. Larger crystals resulted in darker colors, and the average mesh opening was important for differentiating sensory color. The study on brown sugar color can assist the food industry in classifying sugar for direct consumption or in final products.

1 INTRODUCTION

According to Mordor Intelligence (2025), it is estimated that the global market of mascavo sugar will register a growth of 8.13% in the next five years, given the increasing demand of various sectors of the food industry, such as in bakery. Mascavo sugar is considered a sweetening product, and it can produce a brown coloration in different shades, with characteristic aroma and flavor. Mascavo sugar is a product obtained directly from the evaporation and concentration of sugarcane juice.

It also contains organic compounds such as polyphenols and flavonoids (Sampaio et al., 2020), which provide nutritional and sensory benefits.

The characterization of the physical and sensory properties of mascavo sugar is important in the production processes to significantly enhance the formulations of industrial products where it is used as a raw material and to offer parameters and recommendations to consumers (Fajardo et al., 1999).

Sugar preservation is mainly related to moisture content, insoluble residues, polarization, ash, granulometry, and color, and the control of sugar crystallization defines the average crystal size and its uniformity (Oliveira et al., 2007).

Mascavo sugar granulometry is an important feature that may directly influence the attributes of color, flavor, solubility, and texture of the products that use it as an ingredient. Smaller sugar crystals dissolve more rapidly, somehow accelerating the process or facilitating the operation, besides presenting a higher hygroscopicity, with a greater possibility of sugar hardening. For the same volume of sugar, the crystal size influences the established dosage, and it may alter sweetness (Oliveira et al., 2007).

Granulometry is directly related to process control conditions, such as product crystallization and drying. Therefore, understanding and characterizing mascavo sugar granulometry is important to ensure quality and standardization, in addition to providing subsidies for possible improvements in processes and optimizing crystal yield and particle size uniformity. It is also important for the verification of the influence on the sensory features – in the case of this study, mascavo sugar color. Therefore, the aim of this research was to evaluate the effect of mascavo sugar crystal size on instrumental and sensory color. The study on mascavo sugar color can assist the food industry in classifying sugar for direct consumption or in final products.

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[1]*Universidade Tecnológica Federal do Paraná, Londrina, Paraná, Brazil.*
[2]*Universidade Federal de São Carlos, Araras, São Paulo, Brazil.*
*Corresponding author: verruma@ufscar.br
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1.1 Relevance of the work

The study demonstrated that mascavo sugar granulometry significantly impacts its instrumental and sensory color. Larger crystals resulted in darker and more intense colors, and the average mesh opening is important for sensory differentiation. It is suggested that the food industry will be able to standardize the color of final products. Thus, the work ensures the repeatability of visual quality, which is important for consumer acceptance.

2 MATERIAL AND METHODS

The study was conducted at the Federal Technological University of Paraná (UTFPR). The general coordinates and altitude for the city of Londrina, where UTFPR Londrina is located, are: latitude: 23° 18′ 36″ S, longitude: 51° 09′ 46″, and altitude approximately 610 m.

2.1 Mascavo sugar samples

Nine mascavo sugar samples from the region of São Paulo were acquired from the same agribusiness in January 2024. The samples were stored at room temperature in their respective packages until analysis, properly coded (A, B, C, D, E, F, G, H, I).

2.2 Granulometry measurement

The granulometric analysis was conducted using stainless steel sieves with nominal aperture sizes of 600, 425, and 300 μm. The fractions retained by each sieve were weighed and transferred to Petri dishes (60 × 15 mm) for subsequent instrumental and sensory color assessments. The mean aperture (MA) was calculated for the original unsieved samples to characterize their initial particle size distribution.

2.3 Instrumental color analysis

For the measurement of mascavo sugar instrumental color, the portable colorimeter Minolta Chroma Meter CR – 400 was used, CIELAB scale, observer/illuminant 1 10º/D65, obtained by moving the equipment, in three positions of the plate. Coordinates L*, a* (shades from red to green), and b* (shades from yellow to blue) were determined, and the hue value was calculated for the original sugar: $ho = tang^{-1} (b^*/a^*)$ (Konica Minolta, 2007).

2.4 Sensory color analysis

The sensory tests of the mascavo sugar samples were performed at the Laboratory of Sensory Analysis in individual cabins under white light. The Petri dishes with the samples were coded with three digits and simultaneously presented for the sensory evaluation. The panel included 20 untrained panelists. The color difference ranking test (International Organization for Standardization [ISO], 2006) was employed for the sugars retained in three meshes, and the paired comparison test of color difference was used for the sugars retained in two meshes (Associação Brasileira de Normas Técnicas [ABNT], 1994). Project approved at CEP CAAE: 75804723.7.0000.0165.

2.5 Chemical analyses

The original samples of mascavo sugars were analyzed regarding the moisture content by the gravimetric method (oven at 105 °C), polarization, and conductimetric ash content, using the methodology of the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) (De Whalley, 2013), modified for mascavo sugar.

2.6 Statistical analysis

For the statistical analysis of the instrumental color and granulometry data, a factorial analysis was performed, employing the method of principal component analysis (Mingoti, 2007). The Friedman test was employed for the sensory ranking test, using the table described by Christensen et al. (2006). The interpretation of the results of the paired comparison test was based on the total number of judgments *versus* the number of correct judgments. If the number of correct judgments was higher or equal to the tabulated value, it was concluded that there was a significant difference (ABNT, 1994). All analyses were performed with $p \leq .05$ of significance.

3 RESULTS AND DISCUSSION

3.1 Granulometry measurement

Regarding the results of the retention of each sugar in each mesh (Figure 1), it was verified that seven sugar samples were retained in three meshes, and the others (D, E), in two meshes. The study demonstrated that the mascavo sugars presented varied crystal sizes in the meshes used (600, 425, and 300 μm).

There was a variation for the mesh of 600 μm, with 18% of retention for sample G up to 56% for sample F; for the mesh of 425 μm, from 10 (sample G) to 60% (sample D) of retention, and, finally, for the mesh of 300 μm, there was a variation from 10 (sample A) to 72% of retention (sample G) (Table 1).

Regarding the results of the instrumental analysis of color, it was verified that the luminosity (L*) of the nine mascavo sugar samples retained in the mesh of 600 μm presented values from 54.16 to 41.16; in the mesh of 425 μm, the values was between

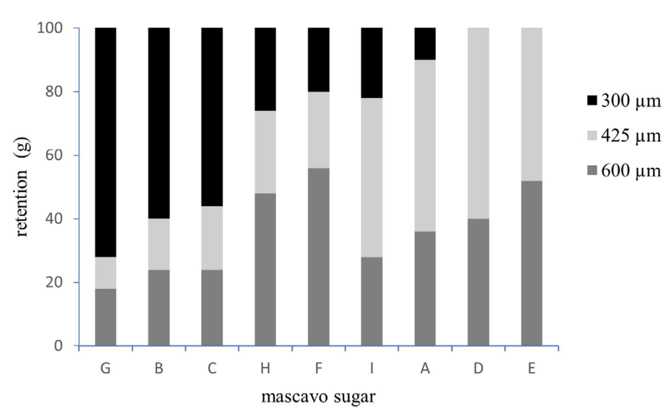

Figure 1. Results of the retention obtained for each mascavo sugar sample.

Table 1. Results of the comparison of variables L*, a*, and b*, between fractions within each mascavo sugar sample.

Sample	µm	L*	a*	b*	Sensory difference in color	Easy RGB
A	600	54.16c	5.72a	16.22b	53a	
A	425	57.14b	5.85a	18.32a	38b	
A	300	58.49a	5.37b	17.98a	29b	
B	600	50.60b	6.98ab	17.51a	51a	
B	425	50.91b	7.54a	17.60a	41a	
B	300	54.46a	6.46b	17.07a	28b	
C	600	47.41b	7.01a	14.63a	53a	
C	425	50.16ab	7.31a	16.54a	45a	
C	300	53.41a	6.03b	14.41b	22b	
D	600	46.70b	6.73a	13.73b	15a	
D	425	49.42a	7.44a	16.23a	5b	
D	300	-	-	-	-	
E	600	41.16b	5.13b	9.25b	19a	
E	425	45.09a	6.16a	13.06a	1b	
E	300	-	-	-	-	
F	600	44.55a	6.19b	12.68b	58a	
F	425	45.84a	7.08a	14.43a	32b	
F	300	45.80a	6.75ab	14.71a	30b	
G	600	46.13b	6.09b	12.76b	55a	
G	425	50.08a	7.73a	16.49a	35b	
G	300	48.70ab	5.65b	12.17b	30b	
H	600	47.65b	8.02a	15.60a	49a	
H	425	48.70b	9.0ab	17.19a	35b	
H	300	52.60a	7.60b	15.57a	36ab	
I	600	43.98b	6.10b	11.74a	49a	
I	425	44.65ab	6.97a	12.99a	44a	
I	300	46.94a	5.72b	11.98a	27b	

RGB: red green blue; L* = 0 (black) to 100 (white); *a** = shades from red (0 + a) to green (0 – a); b* = shades from yellow (0 + b) to blue (0 – b).[1] Values followed by the same letter vertically (per sample) do not differ significantly by the Tukey's test. [2]Values followed by the same letter vertically do not differ significantly by the Friedman test (A, B, C, F, G, G, I); minimum difference ≥ 12. Regarding the difference between D and E, the number of hits ≥ 15 ($p \leq .05$). [3]Higher sum = darker color. Easy RGB (digitally created colors). Available at: https://www.easyrgb.com/en/. Accessed on: 03/28/2025.

57.14 and 44.65; and in the mesh of 300 μm, between 58.49 and 45.80 (Table 1). Comparing the meshes for each sugar, it was observed that, for L*, the values increased as crystal sizes decreased; in other words, the sugar samples became clearer, with crystal size influencing color intensity, as confirmed in a study described by Fajardo et al. (1999). Eight of the nine sugar samples studied presented similar results. For the results of variable a*, for the mesh of 600 μm, there was a variation of the values between 5.13 and 8.02; in the mesh of 425 μm, the variation occurred from 5.85 to 9.01; and in the mesh of 300 μm, between 5.37 and 7.60 (Table 1). It was verified that, for all samples, the results of mesh 425 μm increased the values of a*, indicating a more reddish color, and when they were retained in the mesh of 300 μm, there was a decrease in the red shade.

Analyzing variable b*, it was verified that in the mesh of 600 μm, there was a variation between 9.25 and 15.60; for the mesh of 425 μm, the variation was from 12.99 to 18.32; and in the mesh of 300 μm, between 11.98 and 17.98 (Table 1). Regarding the values of the determinant b*, samples B, H, and I did not show any difference between meshes; for samples A, C, D, and E, the values increased b*, making the samples more yellowish; and for sample G, the value increased in the mesh of 425 μm and decreased on the sieve of 300 μm. It was verified that, in all meshes used, it was possible to find a wide variation of the values of L, a*, and b*.

The variations in mascavo sugar color are related to factors such as sugarcane composition, which is affected by cane variety, variations in the weather, soil, and cultural traits (Jaffé, 2015), extrinsic factors, such as materials foreign to the stalk or compounds produced by microorganisms due to their action on the stalk sugars, and processing.

According to Alves et al. (2024), the variability in the physicochemical characteristics of mascavo sugar represents a challenge for the sugar industry, since coloration may result from different complex reactions among sugarcane constituents or throughout the sugar production and processing steps.

For the sums obtained in the sensory analysis of difference (variation from light color to dark color), all sugar samples retained in the mesh of 600 μm were darker (Table 1). For the samples B, C, and I, it was verified that the panelists noticed a change in sugar color from the mesh of 600 μm to the mesh of 300 μm, whereas for the other samples, the perception of color difference occurred on the second mesh (425 μm).

In a study described by Richardson et al. (2018), when commercial and mascavo sugars with different granulometries were added in the production of chocolate brownies, it was verified that the dark color and the sweetness of the brownies increased ($p < 0.05$) as the sugar crystal sizes decreased. Therefore, the alteration in the sugar crystal sizes affected the physical and sensory properties of the chocolate brownies.

3.2 Chemical analyses

The results of the chemical analyses of the original mascavo sugars are presented in Table 2. It was observed that moisture varied between 1.41 (G) and 3.05% (F), and this variation may interfere with retention, as in the case of sample F (highest moisture content – 3.05%), which obtained the highest retention (56%) on the mesh of 600 μm. Polarization varied between 80.93 (F) and 88.71 (G), and the ash content varied between 1.64 (F) and 2.94% (E). These values are in accordance with the ranges described by Verruma-Bernardi et al. (2007) and Generoso et al. (2009).

From the ratio of retention on the meshes of 600, 425, and 300 μm (Figure 1), the weighted means for variables L*, a*, b*, hue, and MA were estimated for each sample (Table 2).

According to the concepts described by Mingoti (2007), it was possible to observe that the loadings of the variables moisture and polarization were concentrated in Factor 2; nonetheless, they have opposite signs. Likewise, the variable ashes have the same loading in Factors 1 and 2, with the opposite sign not representing a potential variable to differentiate the samples. It was observed that the variable a* presented a significant loading in Factor 3; however, this variable is associated with the calculated variable of the hue angle of the sugars. Therefore, the next potential variable to compose a fourth factor is variable MA (Table 3). With the purpose of grouping the variables into two factors, a factorial analysis was performed employing the method of principal component analysis.

The application of the factorial analysis, including only the variables L*, hue, and MA, allowed their distribution into two differentiating factors of the samples, as observed in Figure 2.

The factorial analysis was performed with the samples that passed by three meshes, to group the variables L*, hue, MA, and the sensory analysis of color difference into two factors (Table 4 and Figure 3), and the values of the loadings of the variables were verified in Factors 1 and 2 after applying Varimax rotation,

Table 2. Results of the chemical analyses, instrumental color, hue angle calculation, and MA estimate of the original mascavo sugars.

Sugars	Moisture (%)	Polarization (°Z)	Ashes (%)	L*	a*	b*	hue (h°)	MA (μm)
A	1.92	88.65	1.92	56.20	5.76	17.53	71.82	476
B	1.98	87.44	1.69	52.97	6.76	17.26	68.62	392
C	2.29	84.93	1.86	51.32	6.52	14.89	66.35	397
D	1.74	87.69	2.68	48.33	7.16	15.23	64.83	495
E	2.2	84.74	2.94	43.05	5.62	11.08	63.08	516
F	3.05	80.93	1.64	45.11	6.52	13.51	64.25	498
G	1.41	88.71	2.08	48.38	5.94	12.71	64.96	367
H	1.47	88.63	2.42	49.21	8.17	16.01	62.96	477
I	1.72	87.12	2.91	44.97	6.45	12.42	62.55	447

MA: mean aperture; L* = 0 (black) to 100 (white); a* = shades from red (0 + a) to green (0 – a); b* = shades from yellow (0 + b) to 1 blue (0 – b).

Table 3. Principal component factor analysis of the correlation matrix, unrotated factor loadings, and communalities for moisture (%), polarization, ashes (%), L*, a*, b*, MA (µm), and hue (h°).

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Moisture (%)	−0.309	−0.930	0.173	0.010	0.991
Polarization (°Z)	0.567	0.794	−0.148	0.144	0.994
Ashes (%)	−0.607	0.672	−0.048	0.366	0.957
L*	0.980	−0.074	0.033	0.131	0.984
a*	0.101	0.394	0.838	−0.363	0.999
b*	0.885	−0.053	0.439	0.116	0.993
MA (µm)	−0.509	−0.102	0.507	0.677	0.985
hue (h°)	0.851	−0.354	−0.164	0.347	0.997
Variance	3.5235	2.2468	1.2332	0.8958	7.8993
% Var	0.440	0.281	0.154	0.112	0.987

L* = 0 (black) to 100 (white); a* = shades from red (0 + a) to green (0 – a); b* = shades from yellow (0 + b) to 1 blue (0 – b).

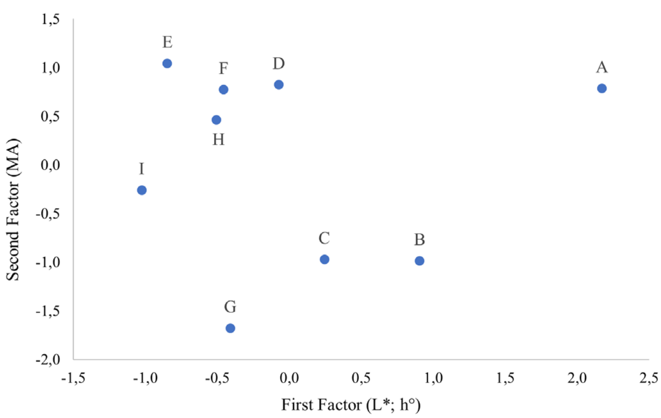

Figure 2. Score plot of the nine original samples of mascavo sugars.

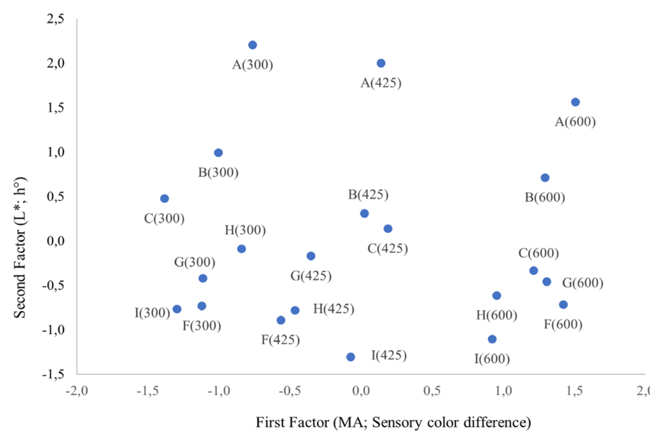

Figure 3. Score plot of the fractionated samples associated with the variable instrumental and sensory color.

Table 4. Principal component factor analysis of the correlation matrix rotated (Varimax) factor loadings and communalities for L*, hue (h°), MA (µm), and sensory color difference.

Variable	Factor 1	Factor 2	Communality
L*	0.241	0.941	0.9430
hue (h°)	0.062	0.973	0.950
MA (µm)	−0.971	−0.148	0.964
Sensory color difference	−0.971	−0.143	0.964
Variance	1.9480	1.8735	3.8214
% Var	0.487	0.468	0.955

L* = 0 (black) to 100 (white); a* = shades from red (0 + a) to green (0 – a); b* = shades from yellow (0 + b) to 1 blue (0 – b).

indicating that Factor 1 is highly correlated with the variables MA and sensory color difference; likewise, Factor 2 is highly correlated with the variables L* and hue.

It was observed, in Figure 3, that the most impactful variable to differentiate the sugar samples by the sensory color difference was variable MA, indicating that the variables L* and hue do not have discriminatory power for different granulometries; nonetheless, they are potential indicators of differences in appearance between the original samples.

4 CONCLUSIONS

Different granulometries interfere in mascavo sugar coloration, being the largest fractions of the mascavo sugars evaluated as darker in both instrumental and sensory color analyses. In sensory color differentiation, it was verified that the variable MA between meshes was the most impactful in discriminating the sugars; nevertheless, variables L* and hue did not have discriminatory power for the different granulometries, but they were indicators of differences in appearance between the samples.

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